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BIOLOGICAL STUDIES IN MASSACHUSETTS.
NO. 3.

BY GEORGE C. WHIPPLE.

GEOGRAPHICAL DISTRIBUTION OF MICROSCOPICAL ORGANISMS.

The geographical distribution of the various microscopical organisms is not only an important subject, but it is an extremely vexatious one. A great deal of study has been given to it, but we are yet very far from understanding this as well as other laws governing this kingdom. Why it is that these organisms grow vigorously in one pond and are at the same time absent from a neighboring one where the conditions are apparently as favorable, or why it is that they suddenly appear in ponds where hitherto they have never been seen, we are unable to say. Solution of these problems can only be accomplished by long continued observation and experiment, and by the working out of the life history of each particular organism. The following statistics are of some value in connection with this subject as they show the relative abundance of the different classes of organisms in some of the important surface water supplies of Massachusetts, together with some of the elements of the sanitary chemical analyses.

For the purpose of this comparison 57 ponds and reservoirs were selected where monthly examinations, both chemical and biological, have been carried on for a number of years by the State Board of Health. The results of these examinations were carefully studied and the ponds (which, for convenience, we may consider to include lakes, ponds and storage reservoirs) divided into groups as shown in Table 4.

The first two columns in this table give the names of the ponds and the cities which they supply. The third gives the depth of the pond, whether shallow or deep. The next four columns show the relative abundance of the four most important classes of organisms, namely, Diatomaceæ, Chlorophyceæ, Cyanophyceæ and Infusoria. The four groups are characterized as follows: and the group to which each pond belongs is indicated by a number.:

Group I. Number of organisms often as high as 1000 per c. c.

Group II. Number of organisms only occasionally as high as 1000 per c. c.

Group III. Number of organisms ordinarily between 100 and 500 per c. c.

Group IV. Number of organisms never above 100 per c. c.

These figures refer not to the numbers present in the average sample of water, but to the numbers during the season of maximum growth. The boundaries of the groups were not sharply defined, and in a number of cases it was hard to tell whether a pond should be classed in group II or III. The last five columns show the ponds divided into classes according to some of the elements of the chemical analysis, namely, color, excess of chlorine, hardness, albuminoid ammonia (in solution), free ammonia and nitrates. In each case four classes are given, division being made according to the schedule given at the bottom of the table.

TABLE No. 4.

CLASSIFICATION OF FIFTY-SEVEN MASSACHUSETTS PONDS AND RESERVOIRS.

The figures refer to the classes to which the ponds belong.

City or Town	Pond or Reservoir	Depth	Diatomaceæ.	Chlorophyceæ.	Cyanophyceæ.	Infusoria.	Color.	Ex. of Chlorine.	Hardness.	Alb. Amo. (dis.)	Free Ammonia.	Nitrates
Abington,	Big Sandy Pond	0	3	4	4	3	1	3	1	2	1	2
Andover	Haggett's Pond	0	3	3	4	2	1	3	3	3	1	1
Ashburnham	Upper Naukeag Pond	0	4	4	4	3	1	1	1	1	1	1
Athol	PhillipstonReservior	0	3	2	2	3	2	2	2	2	2	2
Boston	Reservoir No. 6	+	3	4	4	3	3	3	3	3	2	1
Boston	Reservior No. 4	+	3	3	4	4	3	2	3	4	2	2
Boston	Reservior No. 2	0	3	3	2	4	4	3	3	3	2	**2**
Boston	Reservior No. 3	0	1	3	2	3	3	3	3	4	3	3
Boston	Lake Cochituate	+	1	3	3	3	1	3	4	2	2	3
Boston	Farm Pond	0	3	3	3	1	1	3	3	3	2	3
Boston	Mystic Lake	+	1	1	3	1	1	4	4	3	4	4
Boston	Jamaica Pond	+	1	1	1	3	1	4	4	3	4	4
Brocton	Salisbury Brook Reservoir	0	1	3	4	3	3	2	2	4	2	2
Cambridge	Fresh Pond	+	1	2	2	3	1	4	3	3	4	4
Cambridge	Stony Brook Reservoir	0	1	3	3	2	3	3	3	3	3	3
Danvers	Middleton Pond	+	3	3	4	3	3	2	2	3	1	2
Fitchburg	Scott Reservior	+	1	3	4	3	1	2	2	2	1	1
Fitchburg	Falulah Reservior	0	1	3	3	3	1	2	2	2	2	2
Fitchburg	Meeting House Pond	0	4	4	4	3	1	2	2	2	1	1
Gardner	Crystal Lake	+	3	4	4	3	1	3	3	1	2	2
Gloucester	Dikes Brook Reservoir	0	2	3	4	4	2	1	1	3	3	1
Gloucester	Wallace Pond	0	3	4	4	3	3	2	2	4	2	1
Gloucester	Fernwood Lake	0	2	4	4	3	4	2	2	4	3	2
Hingham	Accord Pond	+	1	3	4	3	1	3	1	1	1	1
Hingham	Fulling Mill Pond	0	1	3	3	3	1	3	3	1	4	3
Hinsdale	Storage Reservior	0	2	2	4	3	2	1	2	2	1	1
Holyoke	Whiting Street Reservoir	0	2	3	2	1	1	2	4	3	1	3
Holyoke	Ashley Pond	0	1	4	4	3	1	2	4	3	2	2

Hudson	Gates Pond	+	3	3	3	3	1	2	2	2	2	2
Leominster	Haynes Reservoir	0	1	2	2	3	2	1	1	4	3	2
Lynn	Breeds Pond	0	1	3	3	3	2	2	3	3	3	2
Lynn	Birch Pond	0	1	3	3	2	2	2	3	4	3	2
Lynn	Walden Pond	0	1	2	1	1	3	1	2	4	4	2
Lynn	Glen Lewis Pond	0	1	1	1	1	3	1	2	4	4	2
Malden	Spot Pond	+	2	2	3	3	1	3	4	3	3	2
Marlboro	Lake Williams	0	3	2	3	3	1	3	3	3	1	2
Montague	Lake Pleasant	+	3	4	4	4	1	2	1	1	2	2
Nantucket	Wannacomet Pond	0	3	3	3	2	1	1	3	4	2	2
Natick	Dug Pond	+	2	3	3	3	1	4	4	3	3	4
New Bedford	Lake Quittacus	0	4	3	3	4	4	2	2	3	2	3
North Brookfield	Doane Pond	0	3	3	4	2	3	3	3	4	3	2
Norwood	Buckmaster Pond	0	2	4	4	1	1	3	2	3	3	2
Orange	North Pond	0	2	3	4	3	3	3	2	3	2	1
Plymouth	Little South Pond	0	4	3	3	3	1	1	1	2	2	1
Quincy	Storage Reservoir	0	1	2	2	3	4	3	2	2	3	3
Rockport	Cape Pond	0	1	3	2	3	1	3	3	3	1	1
Salem	Wenham Lake	+	1	3	3	3	1	3	4	2	2	2
Springfield	Ludlow Reservoir	0	1	1	1	2	2	2	3	4	3	2
Taunton	Assawamsett Pond	0	3	4	4	4	2	3	2	2	1	1
Taunton	Elders Pond	0	4	4	4	4	1	3	1	2	1	1
Westborough	Upper Sundra Reservoir	0	3	2	2	3	2	3	1	3	3	1
Winchester	North Reservoir	0	1	2	1	1	1	4	4	3	3	3
Winchester	South Reservoir	0	3	3	3	3	2	2	4	4	3	2
Winchester	Middle Reservoir	0	4	3	1	3	3	3	3	4	3	1
Woburn	Horn Pond	+	1	1	1	1	2	4	4	4	4	4
Worcester	Lynde Brook Reservoir	0	3	2	2	3	1	2	3	2	3	2
Worcester	Tatnuck Brook Reservoir	0	1	3	3	3	2	1	2	2	2	2

DEPTH. + Deep
0 Shallow

EXCESS OF CHLORINE, 1. 0
2. .01 to .03
3. .04 to .25
4. .25 to

FREE AMMONIA. 1. 0 to .0010
2. .0010 to .0030
3. .0030 to .0100
4. .0100 to

ORGANISMS. 1. Often above 1000 per c.c.
2. Occasionally above 1000 per c. c.
3. Usually from 100 to 500 per c. c.
4. Below 100 per c. c.

HARDNESS. 1. 0 to 0.5
2. 5 to 1.0
3. 1.0 to 2.0
4. 2.0 to

NITRATES. 1. 0 to .0050
2. .0050 to .0100
3. .0100 to .0200
4. .0200

ALBUMINOID AMMONIA (dissolved) 1. 0 to .0100
2. .0100 to .0150
3. .0150 to .0200
4. .0200

COLOR. 1. 0 to 0.30 Nessler Scale.
2. 0.30 to 0.60 Nessler Scale.
3. 0.60 to 1.00 Nessler Scale.
4. 1.00 to —— Nessler Scale.

The figures of the chemical analyses are given in parts per 100,000.

If we consider the ponds with reference to the growths of organisms, we obtain from the above table the following summary:

TABLE NO. 5.

Group	Number per c. c.	Number of Ponds and Reservoirs			
		Diatomaceæ.	Chlorophyceæ.	Cyanophyceæ.	Infusoria.
I	Often above 1000 per c. c.	24	5	7	8
II	Occasionally above 1000 per c. c.	8	11	10	7
III	Usually between 100 & 500 per c. c.	19	29	18	35
IV	Below 100 per c. c.	6	12	22	7

From this it appears that the Diatomaceæ are the organisms most commonly found in large numbers. There are 24 ponds (42 per cent of the ponds considered) which often have these organisms as high as 1000 per c. c., while in only 6 (11 per cent) are they always below 100 per c. c. The Chlorophyceæ are not often found in great abundance, though many ponds contain them in moderate numbers. Only 5 ponds (9 per cent) have growths of 1000 per c. c., while 29 (70 per cent) have growths of from 100 to 500 per c. c. The Cyanophyceæ are not as common as the Chlorophyceæ, but where they do occur their growth is usually greater and they cause more trouble. There are 7 ponds (12 per cent) that commonly have growths above 1000 per c. c., while in 22 (39 per cent) they are never above 100 per c. c. The Infusoria are somewhat more abundant than either the Chlorophyceæ or Cyanophyceæ. 8 ponds (12 per cent) often have growths above 1000 per c. c.; 35 ponds (60 per cent) have growths between 100 and 500 per c. c.

From Table 4 it also appears that 28 ponds (49 per cent) often have high growths of one or more of these classes of organisms at one time or another during the year. Such growths, except in the case of certain diatoms, are almost always noticeable and frequently are very troublesome. In seventeen ponds the Diatomaceæ alone reach 1000 per c. c.; in one pond the Cyanophyceæ alone; and in three ponds the Infusoria alone. One pond has high growths of Diatomaceæ, Chlorophyceæ and Infusoria; two of Diatomaceæ, Chlorophyceæ and Cyanophyceæ; two of Diatomaceæ, Cyanophyceæ and Infusoria. In two ponds all four classes are found in large numbers. There is but one pond where the organisms never rise above 100 per c. c.; there are sixteen where no class of organisms shows numbers greater than 500 per c. c.

For the purpose of determining whether the depth of the pond exercises any important influence upon the growth of the organisms the following table has been compiled. Ponds reported as having a maximum depth of more than 30 feet have been called "deep ponds," and those having a less maximum depth "shallow ponds." This arbitrary dividing line was selected after considering the relation between the maximum and the average depth, the temperature changes at various depths, and the depth to which the water is kept in circulation by the wind. In a general way it may be said that the shallow ponds are those in which the water is kept in vertical circulation by the wind over the greater part of their area and for the greater portion of the year, while the deep ponds exhibit the phenomena of stagnation over a considerable portion of their area.

TABLE NO. 6.

Depth	Number per c. c.	Number of Ponds			
		Diatomaceæ.	Chlorophyceæ.	Cyanophyceæ.	Infusoria.
Deep	Often above 1000 per c. c.	8	3	2	2
Deep	Occasionally above 1000 per c. c.	2	2	1	0
Deep	Usually between 100 & 500 per c. c.	6	8	6	12
Deep	Always below 100 per c. c.	0	3	7	2
Shallow	Often above 1000 per c. c.	16	2	5	6
Shallow	Occasionally above 1000 per c. c.	6	9	9	7
Shallow	Usually between 100 & 500 per c. c.	13	21	12	23
Shallow	Always below 100 per c. c.	6	9	15	5

There are 16 deep and 41 shallow ponds. Of the deep ponds 63 per cent at times have growths of the Diatomaceæ above 1000 per c. c., while of the shallow ponds 54 per cent have such growths. There are no deep ponds where the Diatomaceæ are lower than 100 per c. c., while 15 per cent of the shallow ponds have them lower than that figure. It thus appears that the heavy growths of the Diatomaceæ are somewhat more likely to be found in the deep than in the shallow ponds. The same may be said of the Chlorophyceæ, though the difference is not so marked. 31 per cent of the deep ponds and 27 per cent of the shallow ponds at times have growths as high as 1000 per c. c. The Cyanophyceæ and Infusoria, on the other hand, incline towards shallower water. In the case of the former, 18 per cent of the deep ponds and 34 per cent of the shallow ponds at times have growths of 1000 per c. c., while in the case of the latter the figures are 12 per cent and 32 per cent respectively.

In this connection it would be of interest to show statistically the relation that undoubtedly exists between the growths of organisms and the character of the material forming the bottoms of the ponds, but unfortunately the necessary data is lacking in too many cases. So far as observations have been made, however, it appears that muddy bottoms are very largely responsible for the excessive growth of microscopical organisms.

An important question, and one which is of particular interest to water analysts, is the relation between the growths of organisms and the chemical analysis of the water in which the organisms are found. Unquestionably there is such a relation, and we should very much like to be able to take up a chemical analysis and say " this water contains such and such substances in solution, and, therefore, such and such organisms may be expected to thrive well in it." In other words, we desire to know better the nature of the necessary food supply of the microscopical organisms.

The following tables are designed to show in a very general way the relation between the organisms in our 57 selected ponds and some of the important elements of the chemical analysis. These bring out several important facts.

First, it is seen that the color of a water has an important influence upon the number of organisms that will be found therein. Of the 24 cases where the Diatomaceæ are commonly found higher than 1000 per c. c., 12 (or 50 per cent) occur in light colored waters, i. e., water having a color lower than 0.30

TABLE NO. 7.

Chemical Analyses (parts per 100,000).		Number of Ponds and Reservoirs in which Diatoms are			
		Often above 1000 per c. c.	Occasionally above 1000 per c. c.	Usually between 100 & 500 per c. c.	Below 100 per c. c.
Color (Nessler Scale)	.0 to .30	12	4	9	4
	.30 to .60	6	2	4	0
	.60 to 1.00	6	1	5	1
	1.00 to —	0	1	1	1
Excess of Chlorine	0	4	2	1	2
	.01 to .03	8	1	8	2
	.04 to .25	8	3	10	2
	.25 to —	4	2	0	0
Hardness	0 to .5	2	1	3	3
	.5 to 1.0	7	4	5	2
	1.0 to 2.0	8	0	10	1
	2.0 to —	7	3	1	0
Albuminoid Ammonia (dissolved)	0 to .0100	2	0	2	1
	.0100 to .0150	6	1	5	3
	.0150 to .0200	8	6	7	1
	.0200 to ——	8	1	5	1
Free Ammonia	.0000 to .0010	3	2	5	3
	.0010 to .0030	6	1	10	2
	.0030 to .0100	8	5	4	1
	.0100 to ——	7	0	0	0
Nitrates	0 to .0050	3	3	5	6
	.0050 to .0100	11	3	13	0
	.0100 to .0200	6	2	1	0
	.0200 to ——	4	1	0	0

TABLE NO. 8.

Chemical Analysis (parts per 100,000).		Number of Ponds and Reservoirs in which the Chlorophyceæ are			
		Often above 1000 per c. c.	Occasionally above 1000 per c. c.	Usually between 100 & 500 per c. c.	Below 100 per c. c.
Color (Nessler Scale)	0 to .30	2	5	14	8
	.30 to .60	2	4	5	1
	.60 to 1.00	1	2	8	2
	1.00 to —	0	0	2	1
Excess of Chlorine	0	1	3	4	1
	.01 to .03	1	2	11	5
	.04 to .25	0	4	13	6
	.25 to —	3	2	1	0
Hardness	0 to .5	0	2	3	4
	.5 to 1.0	1	4	8	5
	1.0 to 2.0	1	3	13	2
	2.0 to —	3	2	5	1
Albuminoid Ammonia (dissolved)	0 to .0100	0	0	2	3
	.0100 to .0150	0	4	7	4
	.0150 to 0200	2	5	12	3
	.0200 to ——	3	2	8	2
Free Ammonia	0 to .0010	0	2	7	4
	.0010 to .0030	0	1	13	5
	.0030 to .0100	2	5	8	3
	.0100 to ——	3	3	1	0
Nitrates	0 to .0050	0	2	8	6
	.0050 to .0100	2	6	13	6
	.0100 to .0200	0	2	7	0
	.0200 to ——	3	1	1	0

TABLE NO. 9.

Chemical Analysis (parts per 100,000).		Number of Ponds and Reservoirs in which the Cyanophyceæ are			
		Often above 1000 per c. c.	Occasionally above 1000 per c. c.	Usually between 100 & 500 per c. c.	Below 100 per c. c.
Color (Nessler Scale)	0 to .30	2	4	12	11
	.30 to .60	2	3	4	3
	.60 to 1.00	3	2	1	7
	1.00 to ---	0	1	1	1
Excess of Chlorine	0	2	1	3	3
	.01 to .03	1	3	5	10
	.04 to .25	1	5	8	9
	.25 to ---	3	1	2	0
Hardness	0 to .5	0	2	1	6
	.5 to 1.00	2	2	4	10
	1.00 to 2.00	2	5	7	5
	2.00 to ---	3	1	6	1
Albuminoid Ammonia (dissolved)	0 to .0100	0	0	1	4
	.0100 to .0150	0	3	6	6
	.0150 to .0200	2	5	8	7
	.0200 to ---	5	2	3	5
Free Ammonia	0 to .0010	0	2	1	10
	.0010 to .0030	0	2	9	8
	.0030 to .0100	3	5	6	4
	.0100 to ---	4	1	2	0
Nitrates	0 to .0050	1	2	1	12
	.0050 to .0100	3	4	10	10
	.0100 to .0200	1	3	5	0
	.0200 to ---	2	1	2	0

TABLE NO. 10.

Chemical Analysis (parts per 100,000).		Number of Ponds and Reservoirs in which the Infusoria are			
		Often above 1000 per c. c.	Occasionally above 1000 per c. c.	Usually between 100 & 500 per c. c.	Below 100 per c. c.
Color (Nessler Scale)	0 to .30	5	2	20	2
	.30 to .60	1	3	6	2
	.60 to 1.00	2	2	8	1
	1.00 to ---	0	0	1	2
Excess of Chlorine	0	1	2	5	1
	.01 to .03	1	2	13	3
	.04 to .25	2	3	15	3
	.25 to ---	3	0	3	0
Hardness	0 to .5	0	0	7	3
	.5 to 1.00	3	0	12	2
	1.0 to 2.0	1	6	10	2
	2.0 to ---	4	1	6	0
Albuminoid Ammonia (dissolved)	0 to .0100	0	0	4	1
	.0100 to .0150	0	0	13	2
	.0150 to .0200	5	2	12	3
	.0200 to ---	3	4	7	1
Free Ammonia	0 to .0010	1	1	9	2
	.0010 to .0030	1	1	13	4
	.0030 to .0100	2	5	10	1
	.0100 to ---	4	0	3	0
Nitrates	0 to .0050	0	1	12	3
	.0050 to .0100	3	4	17	3
	.0100 to .0200	3	2	3	1
	.0200 to ---	2	0	3	0

on the Nessler scale, and none occur in water where the average color is above 1.00. The same fact is noticed in the case of the other organisms, but not as strongly emphasized as with the Diatomaceæ. The reason for this is doubtless on account of the difference in specific gravity between the diatoms and the other organisms. The diatoms, by reason of their silicous cell walls are heavy, while the other organisms not only are much lighter, but some of them liberate gas, causing them to keep near the surface. Being thus kept near the surface, the depth to which light penetrates in a body of water makes less difference with the growth of the Cyanophyceæ, for example, than it does with the diatoms, which constantly tend to sink, and which are kept near the surface chiefly by the vertical currents in the water.

The "excess of chlorine" means the difference between the amount of chlorine found in a sample of water and that found in the unpolluted water of the same region. To a certain extent it represents the amount of pollution which the water has received. It is important to know whether this element of the analysis bears any relation to the organisms and whether one may rightly infer that a large growth of organisms in a reservoir is any indication of the pollution of a water supply. A study of the tables shows that only to a small extent does the excess of chlorine influence the number of organisms observed, though there is a slight tendency for heavy growths of organisms to accompany high excess of chlorine. This fact corresponds with the common observation that vigorous growths of organisms are often observed in ponds far removed from any possible contamination.

The hardness of a water, i. e., the abundance of carbonates of calcium and magnesium, appears to have some influence upon the organisms. This is noticed in all four classes, though it is most marked in the case of the Diatomaceæ and Infusoria. For example, of the 10 ponds low in hardness not one ever has the Infusoria as high as 1000 per c. c., while of the 11 ponds high in hardness not one but that has Infusoria above 100 per c. c., and 4 of them commonly have them above 1000 per c. c.

The sanitary chemical analysis ordinarily states the amount of nitrogen present in four different forms, namely, albuminoid ammonia (dissolved and suspended), free ammonia, nitrites and nitrates, which represent four stages in the change of organic to inorganic matter. Since nitrogen is essential to all living matter we naturally expect that organisms will thrive best in waters rich in that element. Our statistics show that this is the case, and that it is true for each class of organisms and for the different conditions of nitrogen tabulated. The free ammonia and nitrates appear to be particularly influential in determining the amount of life present. For example, 10 of the 13 ponds low in free ammonia never show maximum growths of the Cyanophyceæ above 100 per c. c., while 4 of the 7 ponds high in free ammonia commonly have growths above 1000 per c. c.

One must be careful in these matters, however, not to mistake cause for effect. Free ammonia, for example, indicates organic matter in a state of decay, and instead of representing the food of the organisms in question it may represent their decomposition. The interaction of the various organisms is a very complicated question, and to what extent one species lives upon the products of decay of another is not well known. The food supply of the different organisms can only be determined by experiments made upon pure cultures, and this subject is as broad as the host of the microscopical organisms is numberless. For a long time we have been groping in darkness, but the active interest which is awaking in the study of the plankton gives us hope to believe that light has begun to dawn.